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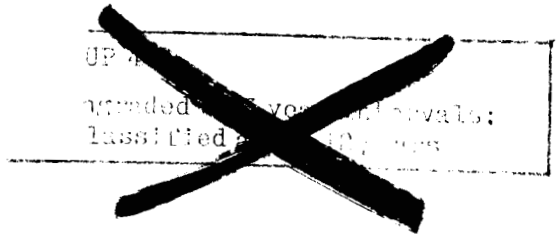
SEMI-ANNUAL PROGRESS REPORT PART III - OSSA PROGRAM SUPPORTING RESEARCH PROJECTS (JANUARY 1, 1964 TO JULY 1, 1964)

Research Projects Laboratory

NASA



George C. Marshall

Space Flight Center,

[illegible]

TECHNICAL MEMORANDUM X-53164

SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

ABSTRACT

This Progress Report presents the Office of Space Sciences and Applications Program of Supporting Research and is Part III of a three part series which describes the George C. Marshall Space Flight Center's Supporting Research Program for the reporting period January 1, 1964 through July 1, 1964.

OSSA tasks are submitted in their respective program areas of Lunar and Planetary ATO, Geophysics and Astronomy,and Meteorological Systems. Within the framework of Sub-Program and Task Area, both in-house and out-of-house tasks convey in condensed form, the purpose, status, accomplishments, problems, and future plans of each study with appropriate illustrations. Finally, an introductory summary gives the highlights of the entire report in reduced form.

It should be noted that the Tracking and Data Acquisition Tasks found in this report are considered separately from the OSSA Program.

Additional copies of this report may be obtained from the MSFC Technical Library, MS-IPL.

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

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TECHNICAL MEMORANDUM X-53164

SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

(January 1, 1964 to July 1, 1964)

This document is classified CONFIDENTIAL because of the intelligence value of the compilation of unclassified reports it contains. Individual reports may be removed and used without classifying them. Caution should be exercised to avoid a sub-compilation of individual reports.

RESEARCH AND DEVELOPMENT OPERATIONS
RESEARCH PROJECTS LABORATORY

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FOREWORD

The George C. Marshall Space Flight Center's Supporting Research Semi-Annual Progress Report was initiated July 1, 1961 in order to facilitate the exchange and dissemination of technical information and research results by providing a qualitative document for the reference of personnel engaged in the promotion of research activities.

This issue, Part I, Part II, and Part III, presents the status of individual tasks under the cognizance of the Research Projects Laboratory during the period between January 1, 1964 and July 1, 1964.

This Center is justifiably proud of the effective utilization of research funds as demonstrated by accomplishments such as those found in this issue of the Report.

C. G. Miles, Jr., Chief
Supporting Research Office

Ernst Stuhlinger, Director
Research Projects Laboratory

ACKNOWLEDGEMENTS

Specific individuals, whose cooperative efforts assisted in the publication of this Report include Mr. Ledbetter (editorial assistance) and Mr. Ziak and staff, Management Services Office; Mr. Smith, Quality and Reliability Assurance Laboratory; Mr. W. Murphree and Mr. J. Cauthen, Aero-Astrodynamics Laboratory; Mr. Daussman, Astrionics Laboratory; Mr. Holland, Manufacturing Engineering Laboratory; Mr. Rodman, Propulsion and Vehicle Engineering Laboratory; Mr. Hill, Test Laboratory; Mr. Doherty, Research Projects Laboratory; and Mr. Bean, Computation Laboratory.

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SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

SUMMARY

This report is concerned with the progress of individual tasks that fall within the scope of the Office of Space Sciences and Applications. Accordingly, tasks are submitted in their respective program areas of Lunar and Planetary ATD, Geophysics and Astronomy, and Meteorological Systems studies.

SECTION I. LUNAR AND PLANETARY PROGRAM

The Lunar and Planetary Program at the Marshall Space Flight Center is presently componse of studies identified with sterilization, advanced concepts, and space chemistry.

Tasks dealing with Planetary Quarantine (sterilization) constitute the major portion of study found in this Program. These studies are developing materials and sub-systems that will be serviceable and reliable after being sterilized by heat with the end view of providing some of the research required for the construction of spacecraft that will land on the planets, such as Mars.

Planetary Quarantine

Some of the information found in this section of the report was previously presented to the Advisory Committee on the Technology of Sterilizable Spacecraft which met at the Jet Propulsion Laboratory, Pasadena, California, in August, 1964. During this meeting, it was pointed out that there are currently four studies identified with the sterilization effort that are being continued into FY-65. These

tasks are developing sterilizable radomes, potting compounds, and thermoelectric materials. Also, a study of particular importance to the sterilization effort is being directed toward the development of guidelines for the design and construction of spacecraft structures that are to be sterilized by heating.

The task, "Design Criteria for Planetary Spacecraft to be Sterilized by Heating" is investigating the effects of heat sterilization on planetary lander structures. This study has already produced a report containing design guidelines that will be valuable to spacecraft designers who must analyze structures for heat sterilization. During this reporting period a new contract was initiated to continue the study which is now investigating such things as multi-layered shells, pressure vessels and the containing cannister. Previous General Electric studies on Mariner and Voyager vehicles are being carefully evaluated in order to define a typical planetary lander to serve as a model for this study.

The study to develop and evaluate materials for use in radomes is progres ing toward the objective of providing a structural protective covering for spacecraft antennas and their mechanisms. Transmission of the antenna signal with a minimum of distortion and attenuation is a factor of prime consideration. The entire system will be compatible with heat sterilization techniques. During this reporting period, several materials have been found which exhibit little change in solar absorptance after 1,000 hours exposure to ultraviolet radiation.

The task, "Research and Development of an Improved Heat Sterilizable Potting Compound" is developing a transparent compound suitable for use on printed circuit boards and for embedding electronic modules. The preliminary evaluation of a group of candidate commercial resins has continued with completion of the moisture recovery phase. Plans call for the syntheses of epoxy-silioxane, urethane-siloxane, and ester-siloxane copolymers.

The initial phase of the study, "Development of a Sterilizable Thermoelectric Cooling System" is being directed toward the development of heat sterilizable thermoelectric materials which demonstrate high figures-of-merit. Among other things, this study has produced techniques for making large single crystals of high temperature compounds. Eventually this task will provide for the design and fabrication of prototype thermoelectric cooling system using the materials presently being developed as the active elements.

The task, "Investigation of Foamed Metals for Application on Space Capsules" is progressing toward the objective of determining the advantages that the foamed metals may have for applications on spacecraft. Moreover, the mechanical and thermal properties of the foamed metals are being investigated under this task, along with the continuation of improvement in processes for

making foamed nickel, and foamed 316 stainless steel. The major accomplishments reported at this time include the preparation and evaluation of nickel and stainless steel foams with controlled density, and the establishment of methods for producing molybdenum and H-11 steel foams.

The task, "Study of Adhesion and Cohesion in Vacuum" is developing engineering data for spacecraft designers to insure separation of instrument capsules and other components from spacecraft which have been exposed to a hard vacuum. The study includes design and fabrication of a vacuum test chamber and the evaluation of different combinations of metal couples. Test apparatus has been constructed, resistance heaters for heating test specimen have been manufactured and the study in general appears to be satisfactorily progressing toward the goals of the program. This study is pointing out that there is little tendency for structural materials to adhere or cohere unless the environmental conditions are sufficiently severe to remove the natural surface films.

Advanced Concepts

Tasks that fall into this area of study are generally concerned with planetary missions using the Saturn Booster with a variety of chemical upper stages. Specifically, these tasks have as their objective the study and application of methods concerning trajectory calculations.

Equations for the path of a low thrust orbital transfer trajectory were developed in the study, "Performance and Guidance Trajectory". This task is developing general perturbation methods for the solution of trajectory optimization problems. Plans are to continue the development of general perturbation solutions of variational equations.

The study, "Development of Methods for Trajectory Calculations..." reports that progress is being made in extending the range of computations for very low thrust optimal trajectories in the neighborhood of a large body. This task is developing computational procedures for determining optimal, three dimensional, low thrust trajectories.

The purpose of the "Optimum Trajectory" study is to ensure that the dynamical system with optimal guidance is stable in a practical sense. Studies are in progress on applications of Liapunov's second method to the optimization of guidance functions for space vehicles. An accomplishment reported at this time consists of the completion of the study entitled, "Local Controllability for Nonlinear Systems". This study defines the concept of local controllability.

Space Chemistry

Studies found in this area of the report pertain to the evaluation of scientific data derived from the release of water ballast by the Saturn vehicle at altitudes above 50 km.

The task, "investigations of Chemical Kinetics in the Upper Atmosphere" is mainly concerned with the study of photo-chemical dissociation of atmospheric constituents and on the effect of water vapor upon these constituents. The design of a portable, self-contained capacitor bank and power supply capable of delivering 18,000 joules at 10,000 volts has been one of the major accomplishments reported at this time.

One of the objectives of "Project High Water Data Analysis" is to develop and establish techniques for recording and analyzing scientific data from effects produced by combustion products of LH-LOX engines in the upper atmosphere. Future plans will include in-house laboratory work to simulate LH-LOX combustion in a vacuum chamber and to make spectral observations.

SECTION II. GEOPHYSICS AND ASTRONOMY PROGRAM

The Geophysics and Astronomy Program is currently being directed toward the study of ionospheric electron content. MSFC in-house research is presently involved in the world wide effort to obtain very accurate, long-term records of the electron content of the ionosphere through the use of Polar Ionosphere Beacon Satellite (BE-A).

Ionospheric and Radio Physics

The task, "Measurement of Ionospheric Electron Content" has the objective of measuring the number of electrons per square meter in the ionosphere by receiving, recording and analyzing signals from scientific satellites. During this period, progress involved the establishment of receiving equipment on Green Mountain in the Huntsville area. An additional station to record data from the BE-B satellite, and possibly the Orbiting Geophysical Observatory, will be constructed at the Alabama Agricultural and Mechanical College at Normal, Alabama.

SECTION III. METEOGOLOGICAL PROGRAM

The only study found in the Meteorological Program during this period involves the measurement of high altitude wind shears. A follow-up on the HOPI-DART program, this study is oriented toward putting the system into operational use.

Meteorological Systems Research

In order to obtain wind measurements between 70 and 90 km, this task is directed toward "Design, Integrate, Fabricate, Checkout and Furnish Fifteen High Altitude Wind Measuring Devices". At this time, there remains only four altitude wind measuring devices to be fired. It should be noted that all aerodynamic problems have been solved. Moreover, these vehicles or devices are performing according to specifications and requirements.

SECTION IV. TRACKING AND DATA ACQUISITION*

Studies in this section of the report are concerned with the development and utilization of tracking techniques; and the investigation of perturbing forces as they may affect the tracking of orbital space vehicles.

The task, "Analysis of Tracking Techniques for Lunar Vehicles" for developing techniques for the computation and determination of orbits in Earth-Moon space, reports among other things, that complete documentation was given for the orbit computational program using Encke's method with Herrick's universal variables.

The purpose of the task, "Investigation and Analysis of the Influence of Perturbing Forces on Tracking of Orbital Vehicles" is to perform an analysis of the effects upon an earth orbit of periodic and continuous venting of gases from the satellite with specific application to the Saturn S-IVB stage. A useful comparison of perturbation magnitudes has been accomplished. This information will be used to assess levels of sophistication in trajectory analysis.

* This section should be considered separately from the OSSA Program.

SECTION I. LUNAR AND PLANETARY PROGRAM

Planetary Quarantine

A. Design Criteria for Planetary Spacecraft to be Sterilized by Heating

Submitted by
(Technical Supervisor)

Ron G. Crawford
R-P&VE-SAA, 536-1659

1. Project Data

Contract Numbers: (1) NAS8-11107, Sept. 20, 1963; May 19, 1964
(2) NAS8-11372, June 30, 1964; July 31, 1965

Contractor: General Electric Company
Missile and Space Division
Spacecraft Department
Philadelphia 1, Pennsylvania

2. Purpose of Project. The purpose of this study is to investigate the effects of heat sterilization on spacecraft and planetary lander structures and to establish and compile guidelines and criteria for the structural design of these vehicles.

3. Technical Status. Although little technical data was available on this subject prior to this study, some important conclusions have been drawn as a result of only six months effort. Problem areas requiring additional work during the remainder of this study and in follow-on studies have been outlined. Many guidelines have been established and it is felt that Document No. 64SD600, Final Report, Contract No. NAS8-11107, "A Study of Design Guidelines for Sterilization of Spacecraft Structures" dated April 9, 1964 would be valuable to engineers who must design or analyze structures to be sterilized.

Multi-layered shells (including crushable materials) pressure vessels, and containing cannister (biological barrier) are currently being investigated.

4. Major Accomplishments. The major problems associated with heat sterilization have been broken into two categories: those resulting from transient thermal gradients and structural degradation due to elevated temperatures. Heat sterilization in a sterile inert gas has been analyzed and judged highly desirable and superior to heat sterilization in a vacuum.

Structural joints were grouped by types, i.e., riveted, bolted, bonded, etc., and qualitative ratings of each joining technique were made.

Many materials, and particularly aluminum, were found to degrade due to overaging when subjected to several cycles of the sterilization environment. Spacecraft should, therefore, be subjected to a minimum number of heat cycles.

5. Problems. The integration of energy absorbing crushable material into the primary structure and concepts for the cannister interface with the lander remain as the primary problem areas at this time. These problems are not considered insurmountable and the objectives of this task should be obtained on schedule.

6. Future Plans. Additional thermal analysis will be performed on a typical lander and on structural joints. Structural investigations will continue on multi-layered shells, space frames, and pressre vessels. Material degradation will be investigated for advanced material such as beryllium. Recommendations on surface finish will be determined. Methods of leak detection with emphasis on avoiding contamination of a previously sterile spacecraft will be investigated.

A small thermostructural vehicle test will be conducted to determine the relationship between predicted and recorded thermal stresses and deflections.

The entire life of a typical spacecraft structure from sub-assembly through sterilization and launch will be considered for all possible design implications.

A design criteria notebook containing simple charts, graphs, tables, and guidelines will be assembled. This notebook will allow a designer or analyst to determine with little effort the effect of heat sterilization on, and ways to improve, a proposed design.

Finally, in future studies, design guidelines and criteria will be updated, added to, and substantiated by full-scale thermo-structural testing. Problem areas will be investigated in greater detail and firm recommendations to guide future structural designs will be made.

7. Illustrations. None.

B. Development of Dielectric Window/Protective Cover Materials for Spacecraft Antennas

Submitted by
(Technical Supervisor)

E. C. McKannan
R-P&VE-MEE, 876-1233

1. Project Data

Contract Number: NAS8-11026, June 27, 1963 - June 27, 1964

Contractor: Hughes Aircraft Company
Culver City, California

2. Purpose of Project. This contract provides for the development and evaluation of materials for use in radomes and antenna covers on spacecraft. The cover must protect and seal the antenna and its associated mechanisms and prevent distortion to the antenna signal. Therefore, the materials must have low deilectric loss properties; high mechanical strength and rigidity; high temperature resistance for sterilization, launch, and planetary atmospheric environments; low gas permeability; and resistance to the effects of the space environment. Since no single material is expected to provide all these requirements, compromises, composites, laminates, and coatings will be studied.

3. Technical Status. Screening tests on candidate materials have been completed. Selected silicones diphenyl oxides, polyimides, and polybenzamidazole have been chosen for further study because they provide a satisfactory combination of required properties: vacuum and ultraviolet radiation stability, low absorptance, low gas permeability, and low dielectric loss properties. Also, alumina, fused silica, and Pyroceram continue to be of interest for thin-walled radomes. Several phenyl silicones, polyesters and gelatins have been eliminated from interest. For reinforcement, quartz cloth has been selected for each of the polymers instead of the standard "E" glass cloth. The lower dielectric constant of quartz makes it more attractive than "E" glass for this application. Also, it has been determined that the use of thermal control coatings on the reinforced plastics has no significant effect on the dielectric loss properties of the substrate material.

4. Major Accomplishments. Several materials (both polymers and ceramics) have been found which exhibit little change in solar absorptance after 1,000 hours exposure to ultraviolet radiation. Dielectric specimens have been fabricated and the dielectric properties of several of these have been measured at 9.28 gigacycles.

5. Problems. None.

6. Future Plans. Testing will continue on candidate materials to determine critical electrical and physical properties.

7. Illustrations. None.

C. Research and Development of an Improved Heat Sterilizable Potting Compound

Submitted by
(Technical Supervisor)

William J. Patterson
R-P&VE-MNP, 876-3834

1. Project Data

Contract Number: NAS8-5499, June 29, 1963 - June 30, 1965

Contractor: Hughes Aircraft Company
Culver City, California

2. Purpose of Project. This contract is directed toward the development of at least one transparent potting compound suitable for use on printed circuit boards and for embedding electronic modules. This material must be capable of withstanding exposure to a temperature of 200° C (392° F) for a continuous 24-hour period without loss of physical or electrical properties. Additionally, the product must be compatible with all parameters of the space environment. Specific requirements for the desired material are as follows:

a. Harness: maximum shore A of 60 at 21°C (70°F)
b. Strength: minimum tensile strength of 1500 psi per ASTM D-412-51T
c. Adhesive characteristics: The material shall demonstrate adhesive characteristics to substrates used commonly in electronic subassemblies.

d. Moisture absorption: Moisture absorption after immersion for 24 hours at 100° C (212° F) shall not exceed 0.196 percent.

e. Thermal properties: The potting compounds shall have the highest practical specific heat and thermal conductivity.

f. Thermal expansion: The desired linear coefficient of thermal expansion is of the order of 10 to 20 x 10^{-6} inches per inch per degree Centigrade.

g. Electrical properties per MIL-S-8516C: Dielectric constant - maximum of 4; dielectric strength - 350 to 400 volts per mil; minimum volume resistivity - 10^{16} ohm-centimeters at 21° C (70° F) and 10^{13} ohm-centimeters at 66° C (150° F) minimum surface resistivity - 10^{12} ohms per square centimeter; minimum insulation resistance - 10^{5} meg-ohms.

3. Technical Status. The preliminary evaluation of a group of candidate commercial resins has continued with completion of the moisture recovery phase. Twenty-four samples which passed the initial screening phase have been fabricated into the 4-rod electrode environmental test configuration and subjected to a temperature of 150° C and a pressure in the range of 10^{-8} Torr for 500 hours continuously. During this interval, the dielectric constant, dissipation factor, and insulation resistance were continuously monitored. It was found that insulation resistance, rather than volume resistivity which was specified in earlier reports, would offer a more meaningful characterization of the materials. All outgassing products from the samples were cryotrapped for analysis by infrared spectroscopy.

4. Major Accomplishments. The Shell epoxy resins, X-24 and H-25, exhibited the best resistance to the effects of environmental testing, as evidenced by their low degree of outgassing during the test interval. Dow Corning R-7501 silicone resin, molecularly distilled, outgassed the least of all the silicone materials tested. Linear coefficient of thermal expansion studies involving quartz fillers indicated a value of 14 x 10^{-6} inches per inch per degree Centigrade for H-25 and X-24 resins, and a value of 25 x 10^{-6} for the R-7501. resin.

5. Problems. No significant technical problems have been encountered to date.

6. Future Plans. The results of efforts expended during the 1963-64 contract year will be extended to guide and support the continuation contract

modification which includes a polymer synthesis program. Synthesis of epoxy-silixane, urethane-siloxane, and ester-siloxane copolymers will be carried out by employing monomers molecularly designed to impart favorable potting compound characteristics.

7. Illustrations. None.

D. Development of a Sterilizable Thermoelectric Cooling System

Submitted by
(Technical Supervisor)

Jackson C. Horton
R-P&VE-MEM, 876-7431

1. Project Data

Contract Number: NAS8-11075, June 29, 1963 - July 29, 1964
NAS8-11452, July 29, 1964 - July 29, 1965

Contractor: Ohio Semiconductor Division,
Tecumseh Products Company
Columbus, Ohio
Battelle Memorial Institute
Columbus, Ohio

2. Purpose of Project. This program is directed toward the development and qualification testing of a thermoelectric cooling system suitable for application in a Venusian Landing Capsule. The initial contract work is for the development of thermoelectric materials which have high figures-of-merit (Z) and are compatible with the space environment. Specifically, the contractor is directed to develop thermoelectric materials which have a figure-of-merit greater than 4.0×10^{-3} per degree centigrade at 25°C (77°F) and which are capable of continuous operation at temperatures from -250°C (418°F) to 300°C (572°F), and at an environmental pressure of 1×10^{-8} millimeter of mercury. The contract provides for an initial theoretical investigation in order to establish the most appropriate approach for developing materials with the specified high figure-of-merit. In this initial study, consideration will be given to such concepts as (1) varying the solid solution concentration of binaries with or without doping agents, (2) selecting new matrices, new doping agents, and new solid state solution alloys, (3) determining the preferential orientation of anistropic materials, and (4) modifying lattice structures and interatomic spacing. Based upon the results of

this initial study, new thermoelectric materials will be developed and identified according to chemical composition and lattice structure, and pertinent thermoelectric properties will be determined at various differential temperatures across the specimen and at widely varying environmental temperatures. The materials which, on the basis of these tests, demonstrate suitable physical properties and high figures-of-merit shall be formed into couples and tested in air and at reduced pressure to determine the coefficient of performance (defined as the rate of heat removal from the cold junction by the electrical power input to the couple).

The second phase of the program is the design, fabrication, and evaluation of prototype thermoelectric cooling systems using the previously developed materials as the active elements. Studies will be made to (1) evaluate the effects of element configuration on system operation (2) develop reliable thermoelectric junction formation techniques (3) provide for efficient system component thermal transfer (4) develop techniques for providing reliable electrical connections in the stated environment (s) and (5) determine the feasibility of multistage cooling. In addition, prototype, compatible electrical power supplies will be designed, fabricated, and tested. Finally, a complete cooling system will be constructed and tested in the required environments to demonstrate the required operating characteristics.

3. Technical Status. The contractor has selected two basic alloy systems for development based on theoretical studies. These are the Ag-Sb-Te type alloys for elevated temperatures and the Bi-Sb system for low temperatures. To date, the contractor has prepared and evaluated approximately 50 alloys in the Ag-Sb-Te system. These alloys consisted of seven major alloy series evolved from the basic $AgSbTe_2$ alloy by major substitutions of Fe, Tl, Au, Se and variations in Te in $AgSbTe_2$. Several host lattices were found which show promise of exhibiting high ratios. Specifically, certain Ag-Te-Sb-Te alloys with low or zero Ag content were discobered with potentially high u/K_t ratios, low resistivity, and transport property values and dependencies on temperature and metallographic structures like Bi-Sb-Te alloys.

4. Major Accomplishments. An improved method of growing $Bi_{1-x}Sb_x$ crystals has been developed which yields much larger single crystals of $Bi_{88}Sb_{12}$ than were available previously. Also, metallographic analyses and crystal orientation methods and techniques have been developed and applied successfully in evaluating the above alloys and crystallographically orienting Bi and Bi-Sb alloy crystals.

Hall Effect, conductivity, and magnetoresistance versus temperature equipment for making measurements in vacuum was completed and used advantageously in evaluating selected alloys. It was determined that the Bi and Bi-Sb crystals have great potential for thermomagnetic and low temperature thermoelectric cooling use respectively.

5. Problems. To data, no significant problems have been encountered.

6. Future Plans. The following work is planned for the immediate future:

a. Prepare certain selected alloy modifications in the Ag-Fe-Te system with (1) high electron mobility and large positive thermoelectric power, and (2) high electron mobility and negative thermoelectric power

b. Complete the $Ag_{1-x}Au_xSbTe_2$ investigations

c. Grow optimized Bi and Bi_{95} Sb_5 crystals

d. Evaluate Bi crystals in the thermomagnetic mode and as thermomagnetic coolers.

e. Evaluate $Bi_{95}Sb_5$ crystals for low temperature n-type thermoelectric cooling with and without magnetic field.

f. Perform transport property and thermoelectric evaluations of Ag-Te-Sb-Te alloys, as necessary, to help ferret out optimum n and p type alloys in this system.

g. If promising high Z, n and p type, alloys are developed in the Ag-Te-Sb-Te system, construct thermoelectric cooling modules to demonstrate cooling characteristics, the temperature range of operation, and performance in vacuum.

7. Illustrations. None.

E. Investigation of Foamed Metals for Launch and Space Vehicle Application

Submitted by
(Technical Supervisor)

H. H. Kranzlein
R-P&VE-MMP, 876-2467

1. Project Data

Contract Number: NAS8-11048, June 24, 1963 - Sept. 30, 1965

Contractor: Ipsen Industries, Inc.
Rockford, Illinois

2. Purpose of Project. The objective of this contract is to develop and evaluate ductile metal foams for possible application on launch and space vehicles. During the first year of this contract, six foamed metals, 316 stainless steel, aluminum, molybdenum, titanium, and H-11 steel are to be developed and evaluated. During the second year, more extensive development and evaluation is to be conducted on four metal foams. Specific contract objectives include development od ductile metal foams with controlled densities, determination of relationship between mechanical properties and density and pore size of metal foams, development of sandwich structures utilizing foamed metal cores, development of variable density structures, and investigation of fabrication and forming methods for producing useable shapes from metal foams.

3. Technical Status. The contractor has developed procedures for producing foams of nickel and 316 stainless steel with controlled densities. Foams of these metals with densities of 18 and 27 percent of theoretical have been produced and evaluated. Data on the mechanical properties, thermal conductivity, thermal expansion and vibration damping capacity of nickel and stainless steel foams are being analyzed and will be reported shortly. Methods for producing foams of molybdenum and H-11 steel have been developed and standardized. Test samples are being prepared and mechanical property evaluation has begun.

The procedures for producing foams of nickel, 316 stainless steel, molybdenum, and H-11 steel are variations of the same basic process. This process involves foaming a slurry of fine metal powder, followed by a two stage sintering operation. In the first stage, organic binders contained in the slurry are driven off and metallic bonding is initiated. The second stage of sintering completes the metallic bonding. All sintering operations are conducted in vacuum, or nitrogen and hydrogen atmospheres. Titanium foams have been produced, but these foams have not been ductile and the densities achieved have been beyond the desired limits. However, sufficient evidence has been obtained to indicate that ductile foams can be produced by the sintering technique.

The contractor is still encountering difficulties in producing ductile aluminum foams. A great number of variations in the sintering process were explored, but as yet none have resulted in a satisfactory foamed aluminum. Effort in this area is continuing.

Brazing studies have been performed on molybdenum foam. Present indications are that strong brazed joints can be produced by conventional brazing m methods.

Development of variable density foams having low density at the center of the cross section and high density at the outer portion of the cross section has been initiated. Two techniques are being studied; layering of green foams of different density, and immersion of a dried low-density green foam in a higher density slurry.

4. Major Accomplishments. The major accomplishments, to date, include the preparation and evaluation of nickel and stainless steel foams with controlled density and the establishment of methods for producing molybdenum and H-11 steel foams. Another significant accomplishment was the determination that titanium foams can be produced by sintering methods.

5. Problems. Development of aluminum foams by the sintering method has continued to be the major problem area.

6. Future Plans. Future work will be directed at evaluation of the relationship between mechanical properties, density, and pore size. Foams of different density and pore size will be studied. More extensive examination of the use of foamed metals for sandwich structures and variable density beams will be initiated. Also, ductile metal foams will be developed and evaluated at densities of less than 10 percent of theoretical.

7. Illustrations. None.

F. Adhesion and Cohesion in Vacuum

Submitted by
(Technical Supervisor)

K. E. Demorest
R-P&VE-MEE, 876-4241

1. Project Data

Contract Number: NAS8-11066, June 29, 1963 - June 29, 1965

Contractor: Hughes Aircraft Corporation
Culver City, California

2. Purpose of Project. The purpose of this program is to determine the conditions of time and temperature which affect the adhesion and cohesion of structural metals. Data acquired from this program should aid spacecraft designers in insuring separation of instrument capsules from spacecraft in the space environment. Properties of candidate materials which appear to affect adhesion are being studied under a simulated space environment obtained in a special test apparatus.

3. Technical Status. Evaluation of the tendency of the selected material couples to adhere or cohere has been completed. The maximum severity of test conditions established as a criteria for adhesion and cohesion included pressures in the range of 5×10^{-9} mm of Hg, loads to 80 percent of the yield strength of the materials, temperatures to 500° C, and contact periods up to 70,000 seconds. Under these conditions the following materials did not bond: 304 steel to 304 steel; 304 steel to A286 steel; 304 steel to Rene' 41 alloy; A286 steel to A286 steel; Rene' 41 alloy to Rene' 41 alloy; 6A1-4V titanium alloy to Rene' 41 alloy; A286 steel to Rene' 41 alloy. Under the same conditions, but with the environmental temperature reduced to 300° C, the following material couples did not bond: 2014 aluminum to 6 AL-4V titanium alloy; 2014 aluminum to 304 steel; 6AL-4V titanium alloy to 6 AL-4V titanium alloy. Copper formed a weak bond to itself at 300° C. The 2014 aluminum alloy showed a tendency to bond to itself, to Rene' 41, and to A286 at 300° C. However, these tests are to be repeated because plastic deformation of the aluminum alloy indicated that the creep strength of the aluminum alloy had been exceeded.

4. Major Accomplishments. It has been demonstrated that there is little tendency for structural materials to adhere or cohere unless the environmental conditions are sufficiently severe to remove the natural surface films.

5. Problems. No significant problems have been encountered on this project.

6. Future Plans. During the next phase of this program another test parameter will be added to the test environment. This parameter (mechanical motion) will simulate the effects of vibration on the mating spacecraft

materials. It films on the material surfaces, and increase the tendency of the test couples to adhere or cohere.

7. Illustrations. None.

Advanced Concepts

A. Performance and Guidance Trajectory

Submitted by
(Technical Supervisor)

W. E. Miner
R-AERO-G, 876-3997

1. Project Data

Contract Number: NAS8-11099, Sept. 19, 1963 - Sept. 18, 1964

Contractor: United Aircraft Corporation
Research Laboratories
East Hartford 8, Connecticut

2. Purpose of Project. To develop general perturbation methods for the solution of trajectory optimization problems.

3. Technical Status. United Aircraft is continuing to devise equations for solution of problems in performance and guidance of low thrust trajectories.

4. Major Accomplishments. Equations for the path of a low thrust orbit transfer trajectory have developed under the following assumptions: (1) Variable-thrust acceleration; (2) The distance between the end condition orbits is small compared to the major axis of both orbits; (3) The following integral is minimized

$$J_1 = \int_0^{t_f} (T/m)^2 \, dt.$$

Complete analytical solutions are obtained in three different sets of variables: (1) rotating rectangular coordinates, (2) rotating special coordinates, and (3) Lagrange's planetary variables.

Progress Report No. 6 on "Studies in the Fields of Space Flight and Guidance Theory" is available.

5. Problems. None.

6. Future Plans. The studies to develop general perturbation solutions of variational equations will be continued.

7. Illustrations. None.

B. Development of Methods for Trajectory Calculations Using Direct Methods of Calculus of Variation

Submitted by
(Technical Supervisor)

W. E. Miner
R-AERO-G, 876-3997

1. Project Data

Contract Number: NAS8-1549, March. 28, 1961 - March 28, 1962
Modification 1 - Extended to March 28, 1963;
Modification 2 - Extended to March 28, 1964;
Modification 3 - Extended to July 31, 1964

Contractor: Grumman Aircraft Corporation
Research Department
Bethpage, New York

2. Purpose of Project. Computational procedures are being developed for determining optimal, three dimensional, low thrust trajectories. Earth-to-Mars studies continued in checking procedures. A Newton-Raphson method is being considered for trajectory calculations.

4. Major Accomplishments. Progress was made in extending the range of computation for very low thrust optimum trajectories in the neighborhood of a large body. The range has not yet been extended to include all the expected cases. Progress Report No. 6 on "Studies in the Fields of Space Flight and Guidance Theory" is available.

5. Problems. None.

6. Future Plans. Extend the range for very low thrust optimal trajectories by converting to state variables that are slowly varying and changing the numerical integrations methods to a high order Runge-Kutta procedure.

7. Illustrations. None.

C. Optimum Trajectory Study

Submitted by
(Technical Supervisor)

C. C. Dearman, Jr.
R-AERO-G, 876-4033

1. Project Data

Contract Number: NAS8-11020, June 29, 1963 - July 28, 1964

Contractor: Martin-Marietta Corporation
Denver Division
Denver 1, Colorado

2. Purpose of Project. To perform research in optimization theory and in the stability of motion of nonlinear dynamical systems; and in particular, to study the relations between Liapunov's second method and the optimization of guidance functions for space vehicle subject to thrust and gravitational forces. The purpose of this research is to ensure that the dynamical system with optimal guidance is stable in a practical sense. As an integral part of this research, investigations will also be made in the determination of the domain of stability, i.e., the determination of the set of all initial values from which the system's motion may originate and satisfy the chosen stability criteria.

3. Technical Status. Studies are in progress on applications of Liapunov's second method to the optimization of guidance functions for space vehicles subject to thrust and gravitational forces.

4. Major Accomplishments. A study entitled, "Local Controllability for Nonlinear Systems," was completed. In this study the concept of local controllability is defined by stating that a dynamical system is locally controllable along a solution trajectory $\varphi(t)$ if for some $t_1 > t_0$ all points in some state space neighborhood of $\varphi(t_1)$ are attainable in time t_1 by trajectories with admissible controls from an arbitrary initial state (t_0, x_0). This is in contrast to completely controllable systems in which every state can be attained in finite time by some control action. Complete controllability is a characteristic of linear systems; local controllability would seem to be characteristic of nonlinear systems.

The nonlinear system

$$\dot{x}(t) = g(t, x(t)) + H(t, x(t))\, u(t),$$

where x is an n-vector, H and n x r matrix, and u an r vector-valued control with $1 \geq r < n$, is studied. If B(t, x) is an (n-r) x n matrix, of maximal rank, such that $B(t, x)\, H(t, x) \equiv 0$, the local controllability of the above system is shown to be closely related to the integrability of the pfaffian system

$$B(t, x)\, dx - B(t, x)\, g(t, x)\, dt = 0.$$

The above nonlinear system is defined to be completely controllable if the associated pfaffian system is not integrable. It is then proved that in the special case of a linear system, this definition yields a criterion for complete controllability equivalent to that of Kalman. This new criterion is useful since it does not depend on the knowledge of a fundamental solution matrix for a time varying linear system. Its use is demonstrated by obtaining the result that an n dimensional system, formed from a single nth order linear time varying differential equation of the form

$$x^{(n)}(t) + a(t)\, x^{(n-1)}(t) + \ldots + a_n(t)\, x(t) = u(t)$$

is completely controllable. (Here u(t) is a scalar valued control). This result was previously known if the functions $a_i(t)$ were constant.

The remainder of the study deals with local controllability in a neighborhood of singular arcs. It is shown that local tests, which depend upon examining

the controllability of the variational equation along a singular arc, will always be non-conclusive. Along an optimal singular arc, the system is not generally locally controllable; however, it is shown by example that singular arcs can exist along which the system is locally controllable.

5. Problems. None.

6. Future Plans. None.

7. Illustrations. None.

Space Chemistry

A. Investigations of Chemical Kinetics in the Upper Atmosphere

Submitted by
(Technical Supervisor)

Dr. Spencer G. Frary
R-RP-N

1. Project Data

Contract Number: Not Applicable

Contractor: MSFC In-house, (Supported by OSSA, Geophysics and Astronomy Programs, Task 41-85-850-37-01-01)

2. Purpose of Project. To investigate Physical-Chemical reaction kinetics in the upper atmosphere. Emphasis will be placed upon the photo-dissociation of water vapor under simulated high altitude conditions.

3. Technical Status. Equipment has been obtained for preliminary studies of the photo-dissociation of water vapor by Ultra-Violet radiation at low pressures. Apparatus for further studies involving the more precise and accurate detection and determination of the various atomic, molecular and ionic species produced has been designed and is now on order.

Included in this equipment is a Bendix Time-of-Flight Mass Spectrometer, a Jarrell-Ash Vacuum Ultra-Violet Scanning Monochrometer and a high capacity condensor bank for energizing flash lamps for the production of ultra-violet radiation for flash photolysis investigations.

4. Major Accomplishments. The design of a portable, self-contained capacitor bank and power supply capable of delivering 18,000 joules at 10,000 volts by the ME Laboratory has been one of the major accomplishments of the past six months.

5. Problems. Delays in obtaining equipment and supplies, difficulty in obtaining adequate space and operating personnel are still our major problems.

6. Future Plans. The equipment now on hand and that on order is to be assembled and tested. Control panels and recording equipment is now being designed to make the number of manual operations in carrying out an experiment minimum. This is quite essential because of the difficulty in obtaining technicians to assist in the experimental program.

7. Illustrations. None.

B. Project High Water Data Analysis

Submitted by
(Technical Supervisor)

Ray V. Hembree
R-RP-P, 876-1936

1. Project Data

Contract Number: NAS8-5064, June 22, 1962 - Sept. 22, 1962
Modification 1 - Sept. 22, 1962 to Jan. 31, 1964
Modification 2 - Jan. 31, 1963 to Jan. 31, 1964
Modification 3 - June 22, 1963 to Jan 31, 1964
Modification 4 - Jan. 31, 1964 to July 31, 1964

Contractor: Georgia Institute of Technology
Engineering Experiment Stations
Atlanta, Georgia

2. Purpose of Project. Phase I: To perform data reduction and analysis of scientific data derived from the release of Saturn ballast chemicals at altitudes above 50 km.

Phase II: Develop and establish techniques for recording and analyzing scientific data from effects produced by combustion products of LH-LOX engines in the upper atmosphere.

3. Technical Status. A technical report "Analysis of Photographic Coverage of the Saturn SA-2 Water Experiment" was published in September 1962. Insufficient data was available for analysis on SA-3 water experiment because of the extreme range of the Saturn prior to second stage ignition.

The specific objective of Phase II of the project was to observe the spectral and radiation characteristics of by-products from the LH-LOX engine. If a change occurred in the spectral or radiation characteristics of the second stage flame as a function of altitude, then at least two possibilities might exist. (1) A change had taken place in the engine combustion chamber with the result that the by-products had changed. (2) The by-products were unchanged as they left the chamber but due to the changing ambient atmospheric conditions (pressure, composition, etc.) the observed radiation pattern had changed.

4. Major Accomplishments. After several false starts during the period October-December 1963, because of changes in launching dates, a set of equipment was taken to Cape Kennedy for SA-5, which took place on January 29, 1964.

Observing stations were established at Vero Beach, Florida, and on Grand Bahama Island. A modified 51 gun director was set up at each of the two stations and was used as a tracking mount for the following instruments: (1) split type Spectrograph, f/1.8 camera lens used at f/11, 600 lines/mm grating blazed for 7500 A region, 35mm IR film, 1/5 sec exposure time; (2) mod IV 35mm boresight camera with 10 inch f/4.5 lens, with High Speed IR film No. 25 filter, operated at 5 ft/s; (3) infrared Image Converter Telescope with No. 25 filter; (4) ultraviolet Image Converter Telescope; (5) spectral Polarization Recorder using 35mm film and 10-inch lens.

The spectrograph was designed to observe the OH radiation bands in the near infrared and to monitor their variation and intensity as a function of rocket altitude.

The Mod. IV cameras were designed to give a rapid sequence of photographs of the infrared portion of the spectrum for correlation with the spectrographs.

The infrared image converter telescope was to be used as a tracking device and to give a visual observation of the transmission of infrared radiation through the earth's stmosphere.

The ultraviolet image converter telescope was used in a manner similar to the infrared unit except that the ultraviolet OH radiation is attenuated by atmospheric ozone. A quantitative study of the OH attenuation with rocket altitude would give ozone distribution and the height of maximum ozone concentration.

The spectral polarization recorders were designed to be used as wideband spectrometers and to provide some general information about the scattering process.

5. Problems. The Saturn was launched during daylight hours, therefore making spectrography extremely difficult due to high intensity sky background. In addition, the radiation from the LH-LOX flame is not in the visible region of the spectrum but must be observed in the ultraviolet and infrared regions, hence tracking of the second stage was also difficult.

Since only a single mount was available at each site, it was necessary to put all the equipment on this unit. At Vero Beach, malfunction of the spectral polarization recorder a few seconds prior to second stage ignition disrupted the manual tracking operation just long enough that ignition was not recorded and before the target had been reacquired it had disappeared behind a cloud. At GBI, the target was not seen due to cloudy weather.

6. Future Plans. Future plans include some in-house laboratory work to simulate LH-LOX combustion in a vacuum chamber and to make spectral observations. The results of these investigations will provide the basis for the type of instrumentation to be used in an experimental field program in the future.

7. Illustrations. None.

SECTION II. GEOPHYSICS AND ASTRONOMY PROGRAM

Ionospheric and Radio Physics

A. Measurement of Ionospheric Electron Content

Submitted by
(Technical Supervisors)

Charles R. Baugher
R-RP-S, 876-1356

Eugene A. Mechtly
R-RP-S, 876-1141

1. Project Data

Contract Number: Not Applicable

Contractor: Not Applicable, MSFC In-House

2. Purpose of Project. The Marshall Space Flight Center's Ionospheric Beacon Satellite program was conducted from January through June of 1964 principally by four individuals. Dr. E. A. Mechtly, Chief, Scientific Flight Payloads Branch, was the principal investigator and served as the program's director; Mr. C. R. Baugher, Scientific Flight Payloads Branch, served as Dr. Mechtly's assistant and is using this research as the basis of a thesis for a Masters degree from the University of Missouri at Rolla; Mr. W. N. Edens, Astrionics' Green Mountain Station, was responsible for data acquisition; and Mr. F. A. Rodrigue, Computation Laboratory, served as computer and orbit mechanics specialist.

The project had its beginning in 1959 when the first usable data was taken by studying the effects of the ionosphere on linearly polarized radio signals from Explorer VII (1959 Iota 1). This data was used for determinations of the electron content of the ionosphere. The information was derived by determining the number of rotations of the plane of polarization of this linearly polarized signal as it passed through the ionosphere. The number of rotations (called Faraday rotations) is proportional to the number of electrons between the satellite and the ground-based recording station.

The project is currently involved in the world wide effort to obtain very accurate, long term records of the electron content of the ionosphere through the use of Polar Ionosphere Beacon Satellite (BE-A). When launched, this satellite will transmit a linearly polarized beacon signal on 20, 40, 41, and 360 MHz, and will produce much more accurate results than those from Explorer VII which transmitted only a 20 MHz beacon. This large number of frequencies enable one to measure electron content not only from Faraday rotation records but provide a second powerful tool.

This second tool, called dispersive Doppler shift, is based on the principle that the wave length of a signal transmitted from the satellite undergoes a change as the signal is propagated through the ionosphere. Although this change is directly proportional to the electron content of the ionosphere, it is inversely proportional to the frequency of the signal; and, while being considerable at 20 MHz, it is negligible at 360 MHz. By comparing these two signals upon reception, it is possible to detect the amount of shift in the 20 MHz signal and thus obtain an additional measure of the electron content of the ionosphere.

It is hoped that with the addition of these several other radio frequencies and more advanced methods in evaluating the data, it will become possible to determine not only the electron content of the ionosphere but also to determine information on large horizontal gradients of the electron content. This procedure will result in a sort of long term "map" of the ionosphere over a large portion of the United States centered on the local recording station.

3. Technical Status. Although the process of counting the number of Faraday rotations between the satellite and the recording station seems as if it should be fairly uncomplicated, it is actually quite difficult. Indeed, when only one frequency is used, as with Explorer VII, it is impossible to determine the exact number of rotations, and one can determine only the time rate of change of these rotations. However, this information has been quite valuable as a basis for reducing data from Explorer VII and can be used to obtain a good estimation of the number of rotations.

Dr. Mechtly has incorporated the dispersive Doppler equations into the data evaluation program which previously relied upon only the Faraday rotation effect. Basically, this method simultaneously solves the Faraday rotation equations and the dispersive Doppler equations for the electron content and should produce much more accurate results than were previously possible. Mr. Rodrigue has programmed this method on the Computation Laboratory's digital computers, and it is now ready to accept data when such data becomes available.

In order to test the method, Mr. Baugher generated synthetic Doppler and Faraday data and used this as input to the program. This data was generated for specific passes of Explorer VII over Huntsville and used the approximate value of the electron content at the time of the pass as its assumed electron content. It was hoped the program would produce answers somewhere near the assumed electron content although it was not expected that the agreement would be very close since a number of approximations were used. However, the program's results were within ten percent of those predicted and in some cases within five percent. It was interesting to note that the results from the program were in all cases larger than those predicted by the synthetic data. It was then decided to use the Faraday rotation portion of the synthetic data to check the results of the programs used with Explorer VII against the results of the new program. Although the Explorer VII program also produced results which were approximately ten percent of those predicted, the deviation was now in the other direction with the calculated values too small. This produced some amount of disagreement between the two programs which is, as yet, unexplained. The results of some representative calculations are plotted in Figure 1. It is hoped that actual data from the satellite will help resolve this problem.

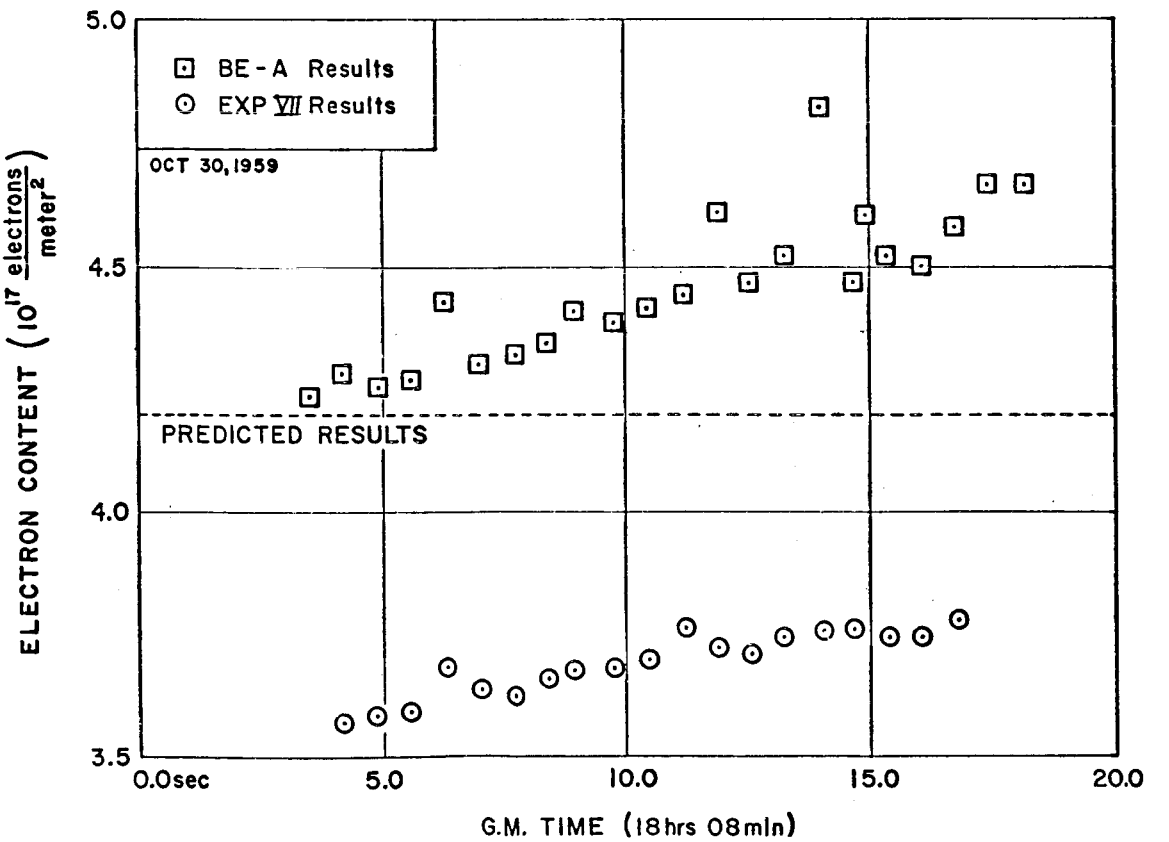

FIGURE 1. COMPARISON OF EXPLORER VII AND BE-A PROGRAMS WITH SYNTHETIC DATA INPUT

Mr. Baugher also devoted time to developing a ray tracing technique for use in reducing data from BE-A. Although this method is more accurate than those presently employed, it consumes considerable computer time and when completed will probably have limited uses. The present methods, however, are very inaccurate when applied to data received when the satellite is below an elevation angle of fifty degrees, and the program may be quite valuable in this area.

a. Green mountain operations. At present, all data recording is accomplished by Mr. Edens at Astrionics' Green Mountain Station. The receiving equipment at this station consists of AVCO-Crosley radio receivers capable of receiving the four frequencies which the satellite is transmitting and internally comparing the 360-MHz signal with any of the other three frequencies to obtain dispersive Doppler data. Faraday rotation data is received directly from the dipole antenna. Additional radios receive the 226.5-MHz timing signal transmitted by Computation Laboratory and provide a very accurate time record. The output of these several receivers are recorded on magnetic tape for permanent storage and automatic reduction and on oscillographic charts for preliminary evaluation and manual reduction.

Since the Beacon satellite has been rescheduled a number of times, beginning in December, 1962, the technical preparations for recording data have been complete for some time and were on a standby basis at the first of the year. During the latter part of February, Mr. Edens returned the equipment to its "ready" status for an attempted launch in mid-March. It was discovered, due to a recent change in the automatic data reduction equipment at Computation Laboratory, the Green Mountain equipment was no longer compatible. This difficulty was corrected shortly before the launch, and the entire system was completely operational on March 19, 1964, the day of the launch.

The lift-off of the Thor-Delta launch vehicle came at approximately 5:13 a.m., CST. At 5:17:41 a.m., CST, the 20 MHz signal transmitted by the satellite was received at the Green Mountain station. The signal strength was approximately -135 dbm, and the signal was heard for eighteen seconds. However, the satellite failed to orbit, and the station was returned to a standby basis. It is presently awaiting an attempt to launch the back-up satellite (BE-B) in mid-September.

b. Data reduction. The data recorded on magnetic tape at the Green Mountain station will be carried directly to the Marshall Space Flight Center Computation Laboratory. This tape will contain a record of Faraday rotations and dispersive Doppler shift of the satellite's signals, as well as a very accurate record of the time. The dispersive Doppler and Faraday rotation data

FIGURE 2. GREEN MOUNTAIN TRACKING STATION

FIGURE 3. DIPOLE ANTENNA - GREEN MOUNTAIN

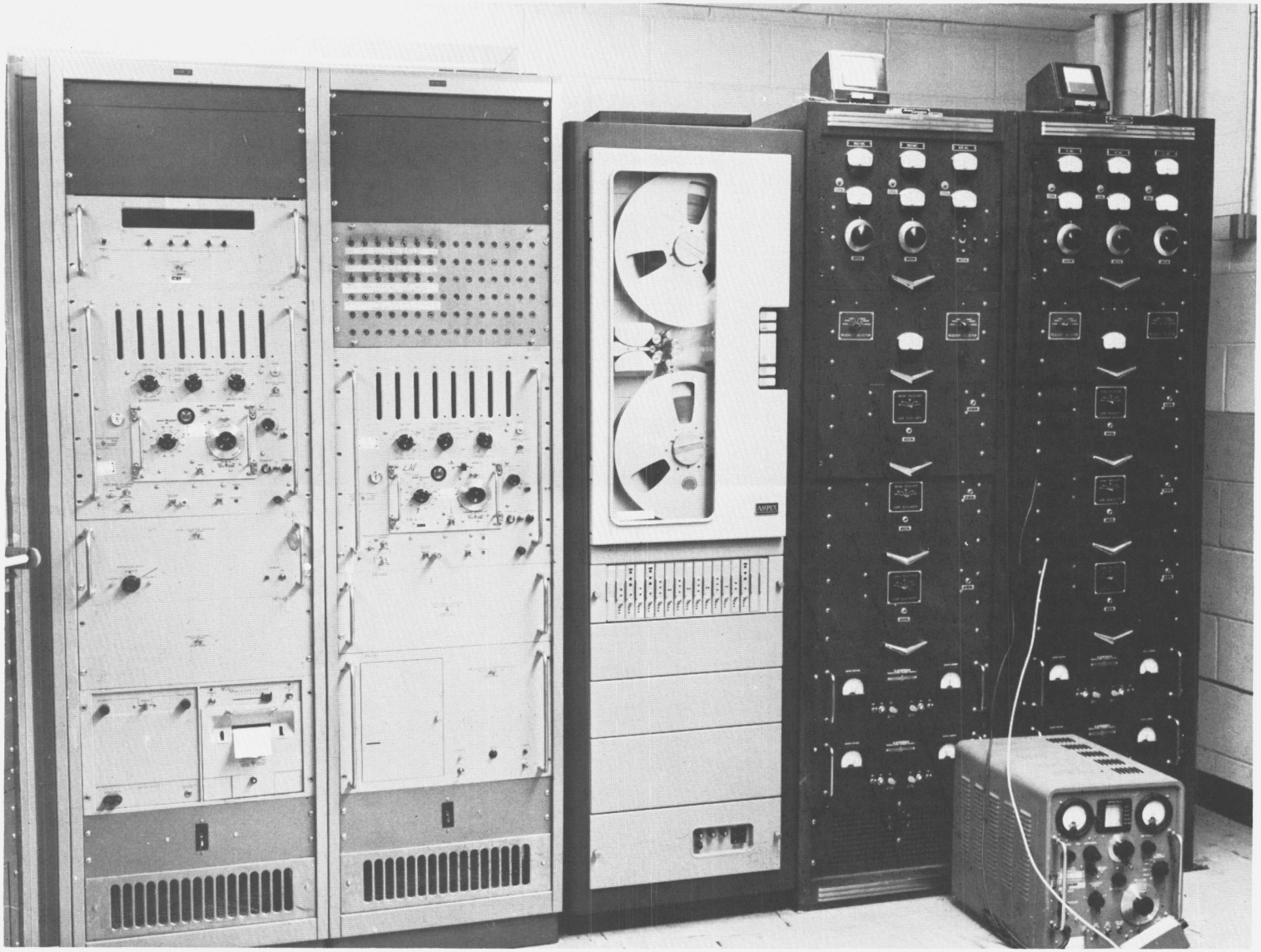

FIGURE 4. AVCO - CROSELY RECEIVERS AND SUPPORTING EQUIPMENT - GREEN MOUNTAIN

appear on the record as a slowly varying voltage with a frequency varying from about twenty cycles per second to almost zero cycles per second. It is presently intended that this data will be digitized by the automatic data reduction equipment at Computation Laboratory and fed directly into the computers for evaluation. This automatic data reduction equipment will "sample" the record at the rate of a thousand times a second and will relate the data to the time record.

Although this technique has not been rigorously tested as yet due to a lack of recorded data, similar operations have been carried out by this equipment and there is nothing to indicate that it will not operate as planned.

The automation of the data reduction portion of this program has removed what is probably the most forbidding part of the effort. In the past, hundreds of man-hours have been spent manually inspecting oscillographic records and digitizing the data. This has produced a situation in which the whole process of data evaluation ran at the slow speed of the digitizing. Additionally, since the output of the data reduction equipment can be fed directly into the computers, the necessity of manually programming each bit of data into the computers has been eliminated.

4. Major Accomplishments. See the Technical Status.

5. Problems. See Technical Status.

6. Future Plans. During the second half of 1964, an additional station to record data from BE-B (and possibly Orbiting Geophysical Observatory) will be constructed in the Huntsville area. Alabama Agricultural and Mechanical College at Normal, Alabama, has been selected as the site of this station, and work is scheduled to begin in July 1964. This station will be somewhat more accessible than the Green Mountain station and will employ students to record data, particularly during night transits of the satellite.

Considerable attention was given to the problem of selecting equipment which would be both accurate and easy to operate. It was decided that the Magnavox receivers, specifically designed to receive signals from the Beacon satellite, could be effectively employed at the location. An Ampex magnetic tape recorder and a Sanborn oscillographic chart recorder were purchased to record the output of the receivers. In addition, several accessory items, including an oscilloscope and signal generator, were acquired for calibration of the station.

7. Illustrations. Figures 1, 2, 3, 4.

SECTION III. METEOROLOGICAL PROGRAMS

Meteorological Systems Research

A. Design, Integrate, Fabricate, Check Out and Furnish Fifteen High Altitude Wind Measuring Devices

Submitted by
(Technical Supervisor)

Robert E. Turner
R-AERO-YA, 876-2767

1. Project Data

Contract Number: NAS8-5175, Nov. 6, 1962 - Aug. 6, 1964

Contractor: Rocket Power, Inc.
Mesa, Arizona

2. Purpose of Project. To furnish the necessary personnel, equipment and all materials, and do all things necessary for or incidental to design, fabrication, and checkout of a high altitude wind measuring device.

3. Technical Status. There remain only four high altitude wind measuring devices to be fired.

4. Major Accomplishments. Obtaining wind measurements between 70-90 km. These data at this altitude are the only measurements to be obtained at Cape Kennedy, except for three measurements obtained by the Deacon Arrow.

5. Problems. All aerodynamics problems solved and vehicle or devices are performing according to specifications and requirements.

6. Future Plans. None.

7. Illustrations. None.

SECTION IV. TRACKING AND DATA ACQUISITION

A. Analysis of Tracking Techniques for Lunar Vehicles

Submitted by
(Technical Supervisor)

Herman F. Kurtz, Jr.
R-AERO-FO, 876-4257

1. Project Data

Contract Number: NAS8-2689, May 17, 1962 - April 16, 1964

Contractor: Lockheed California Company
Lockheed Aircraft Corporation
Burbank, California

2. Purpose of Project. Review and develop techniques for the computation and determination of orbits in Earth-Moon space from tracking observations, including the effects of uncertainties in the computational model. Develop a computational program for computing orbits and related tracking parameters in Earth-Moon space utilizing Encke's method with Herrick's universal variables.

3. Technical Status. The contract was completed in April 1964.

4. Major Accomplisments. The final report centered upon two tasks. Complete documentation was given for the orbit computational program developed using Encke's method with Herrick's universal variables. A card deck of the program was also provided. The program is coded in Fortran for the IBM 7094. Preliminary results indicate the program was quite successful. The second task was the presentation of several papers on physical constants of the Earth-Moon system, their relationships, their best values, and their uncertainties.

5. Problems. None.

6. Future Plans. A further extension of this contract to emphasize comparison of the Encke program with other programs, and modification to generate tracking partial derivatives utilizing Encke's method was planned. However, this area of work has been discontinued by the contractor. Extension of the work is still desired, but there are no definite plans at present.

7. Illustrations. None.

B. Investigation and Analysis of the Influence of Perturbing Forces on Tracking of Orbital Vehicles

Submitted by
(Technical Supervisor)

H. F. Kurtz, Jr.
R-AERO-FO, 876-4257

1. Project Data

Contract Number: NAS8-11073, June 29, 1963 - June 29, 1964

Contractor: Space Technology Laboratories, Inc.
Redondo Beach, California

2. Purpose of Project. Perform an analysis of the effects upon an Earth orbit of periodic and continuous venting of gases from the satellite with specific application to the Saturn S-IVB stage. Determine the effects of various modes of venting on the orbital ephemeris, determine the effects upon the tracking and determination of the orbit, and compare the venting effects with those due to other physical perturbations of the orbit. Also perform an analysis of the magnitude, character, and uncertainty of specified perturbations (including venting) upon Earth-Moon transit trajectories.

3. Technical Status. The contract was completed in June 1964.

4. Major Accomplishments. Most emphasis was placed upon the analysis of venting effects on Earth orbits. Principal characteristics of venting effects were identified, and considerable data were generated to illustrate the magnitude of the effects. Analytic approximations were provided. A comparison of perturbation magnitudes was made which is useful in assessing levels of sophistication in trajectory analysis.

5. Problems. None.

6. Future Plans. None.

7. Illustrations. None.

SEMI-ANNUAL PROGRESS REPORT

PART III

OSSA PROGRAM

SUPPORTING RESEARCH PROJECTS

(January 1, 1964 to July 1, 1964)

Edited by

Harry J. Coons, Jr.

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This document has also been reviewed and approved for technical accuracy.

Gentry Miles, Jr.

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